Ground Bounce on Broadside Coupled Signals in High Density SSD

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Speaker

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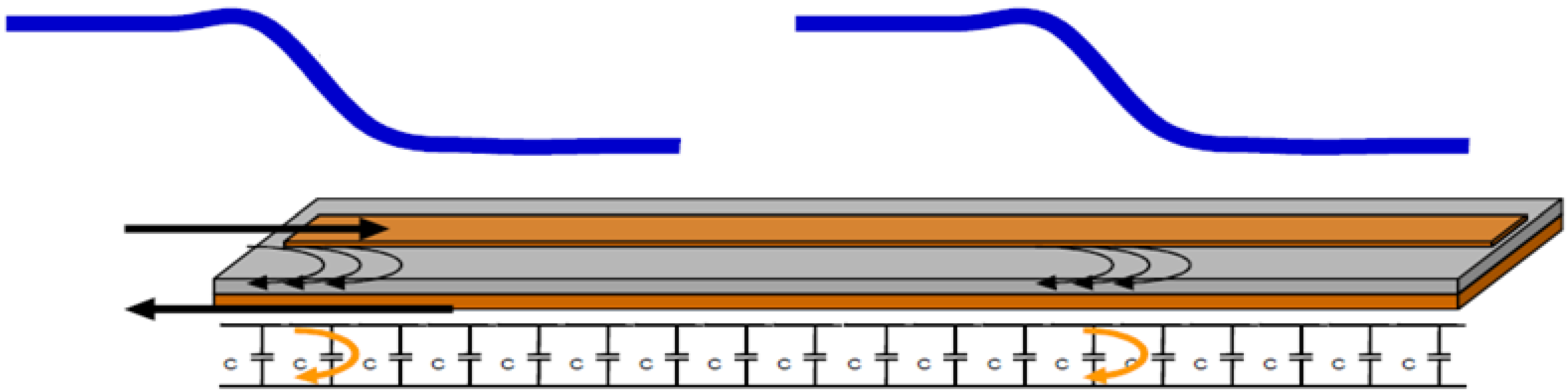
Ground Bounce OR Return Path Crosstalk



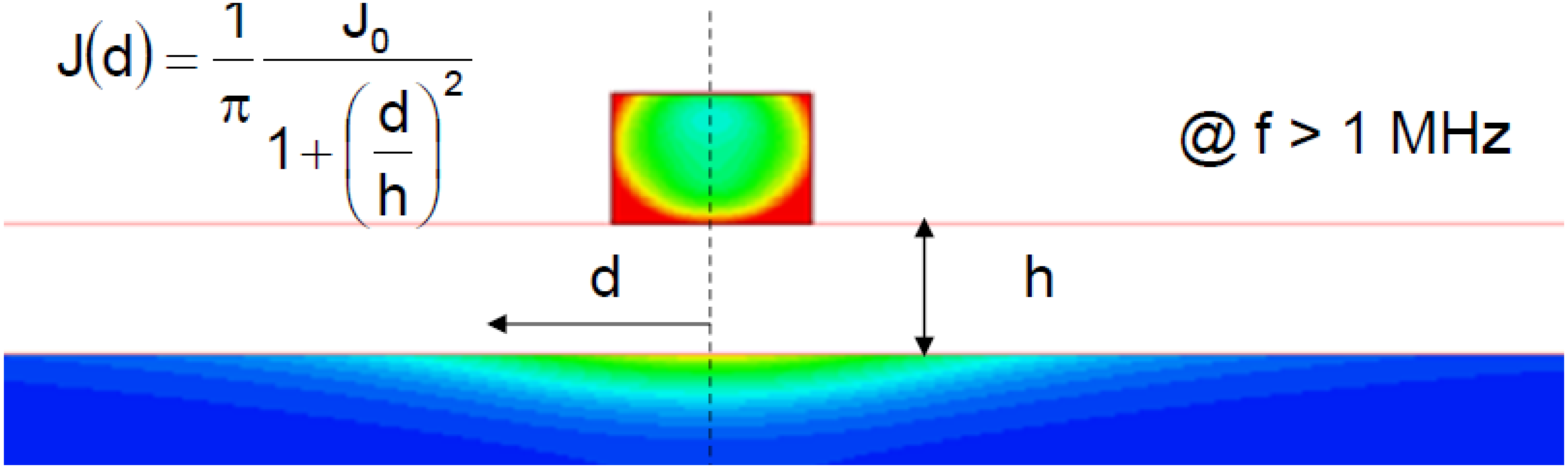
Current loop has two directions

- Direction of propagation
- Direction of circulation

Ground Bounce OR Return Path Crosstalk

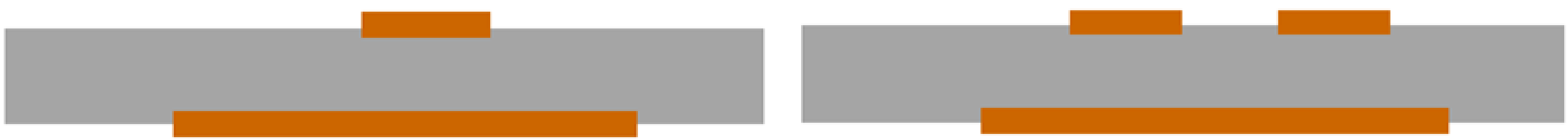
$$J(d) = \frac{1}{\pi} \frac{J_0}{1 + \left(\frac{d}{h}\right)^2}$$

@ f > 1 MHz



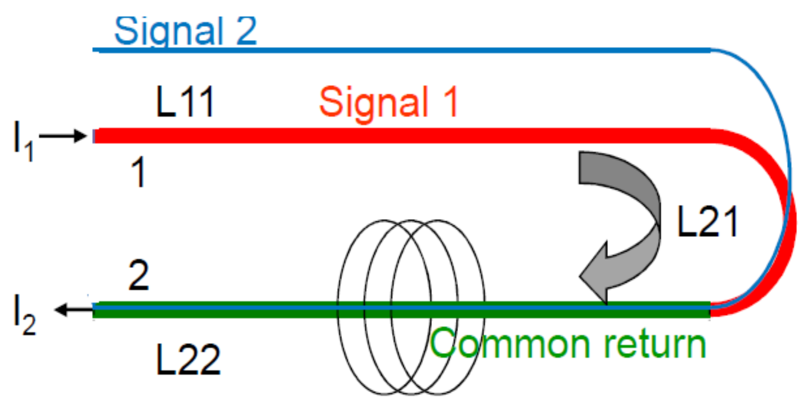
- ➢ Return Current spreads out approximately 3W for 50 Ohms line under the Signal line of width W
- ➢ Return plane width anything more than 3W has no impact
- ➢ If Return path is less than 3W, then it can be treated as return path discontinuity

Ground Bounce OR Return Path Crosstalk



- Return path discontinuity has following effects
  - Increased Loop inductance
  - Increased Impedance
  - If the return currents of 2 signals overlap, it is return path crosstalk OR equivalently called Ground Bounce
  - Capacitive currents remain same but Inductive currents increase

Ground Bounce OR Return Path Crosstalk



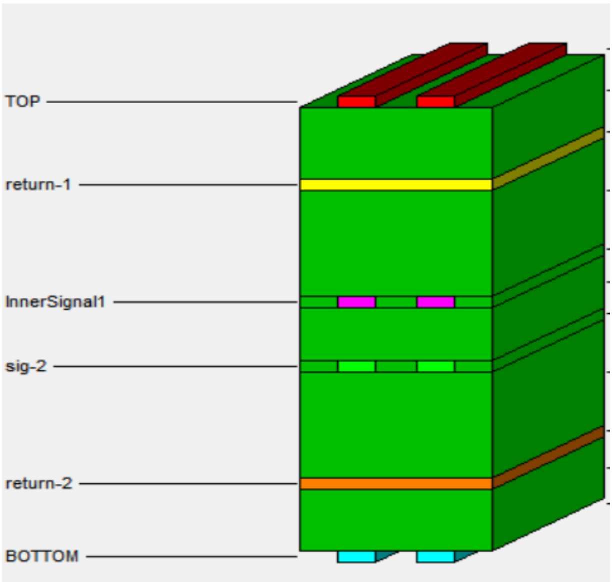
$$V_{gndBounce} = \frac{dN_{total}}{dt}$$

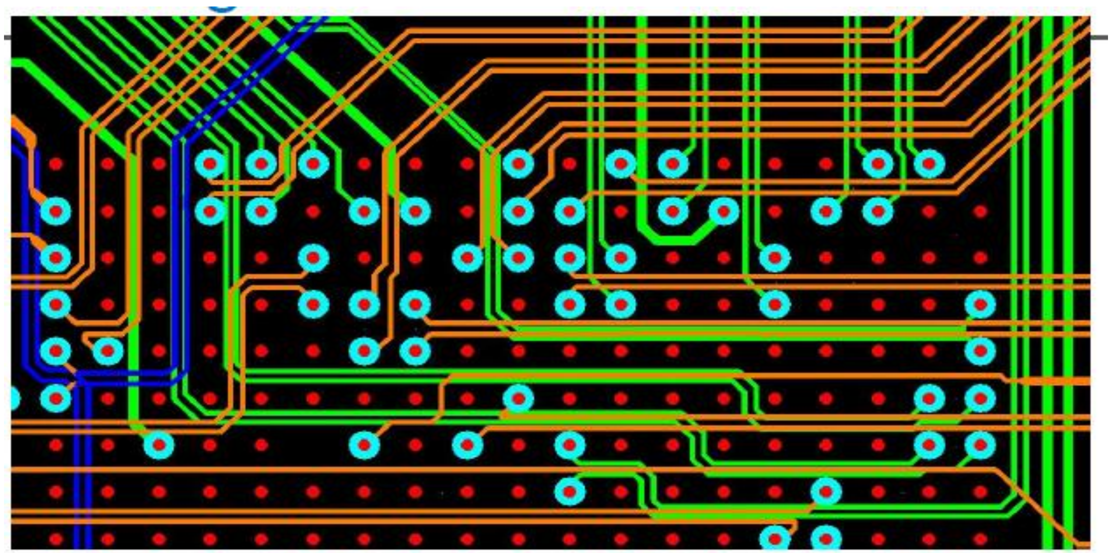
$$N_{total} = L_{22} I_2 - L_{21} I_1$$

$$V_{gndBounce} = \left(L_{22} - L_{21}\right)\frac{dI_1}{dt} = L_{total}\frac{dI_1}{dt}$$

- Voltage across signal 2 has ground bounce voltage in series with it. This is also termed as crosstalk
- Ground bounce noise is related to total inductance in return path
- Wider is Return path, lesser is inductance
- Shorter is Return path, less is inductance
- Do not share return paths or reduce return currents that overlap

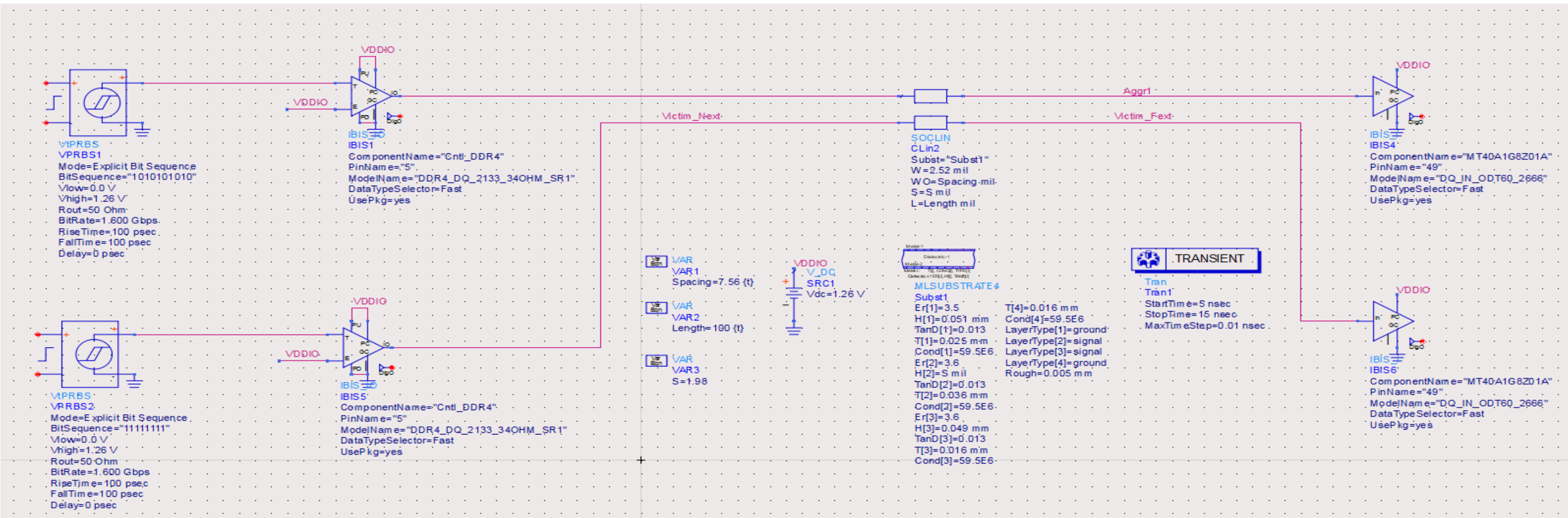
Crosstalk in Broadside Coupled Single Ended Signals





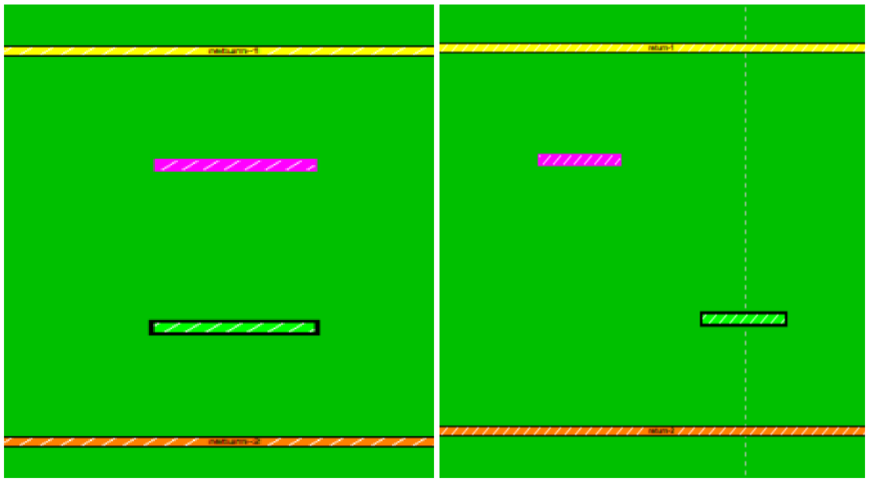
- In High Density SSD, it is very common to have adjacent signal layers in the stack up with reference layers on either sides
- This results in broadside coupled signals especially in BGA escapes for DDR4 signals
- With rise times of DDR4 IO buffers getting sharper and sharper, broadside coupling or equivalently return path sharing increases

Crosstalk in Broadside Coupled Single Ended Signals



- Time domain simulation setup for 2 Broadside coupled signals with DDR4 driver & receiver
- DQ signals with 50 Ohms trace impedance routed on Layer 3 & Layer 4 in 8 layer stack up with Layer 2 & Layer 5 being ground layers
- 1010 pattern is used as Stimulus for DQ signal in L3 while DQ Signal in L4 is driven constant 1

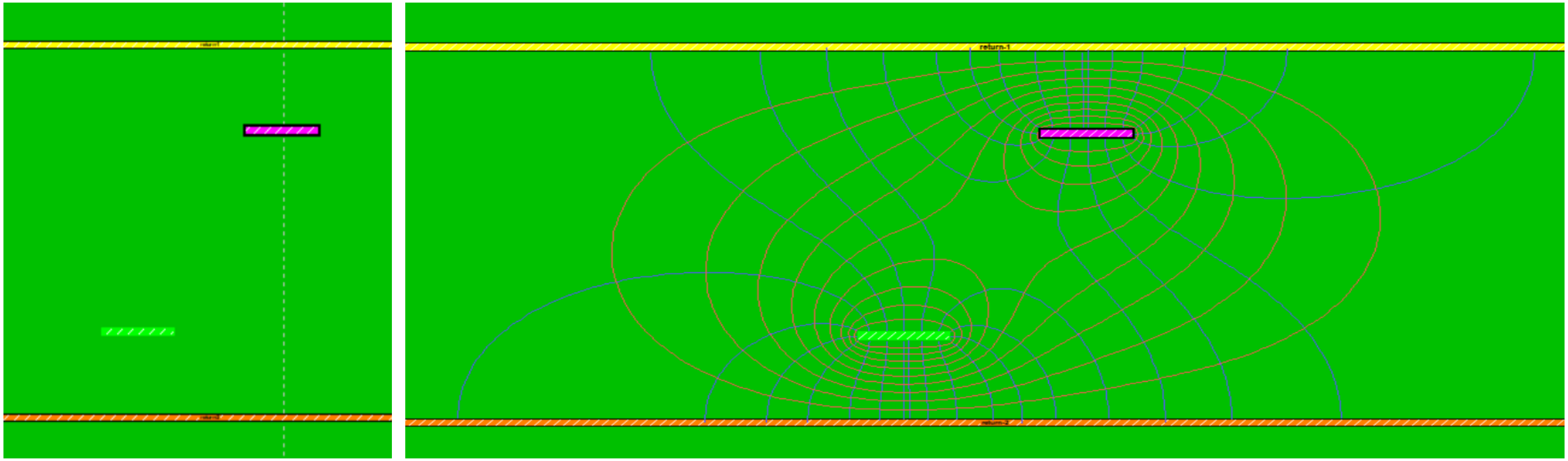
Crosstalk in Broadside Coupled Single Ended Signals



Trace width, W=2.8 mils Broadside Coupling Data							
Coupling length	Offset		Signal Vpp (V)	FEXT Vpp		NEXT Vpp	
	(mils)	W		(v)	(%)	(v)	(%)
50	0	0.0	0.857	0.135	15.75%	0.078	9.10%
50	5.6	2.0	0.857	0.03	3.50%	0.017	1.98%
100	0	0.0	0.87	0.153	17.59%	0.119	13.68%
100	5.6	2.0	0.87	0.037	4.25%	0.027	3.10%

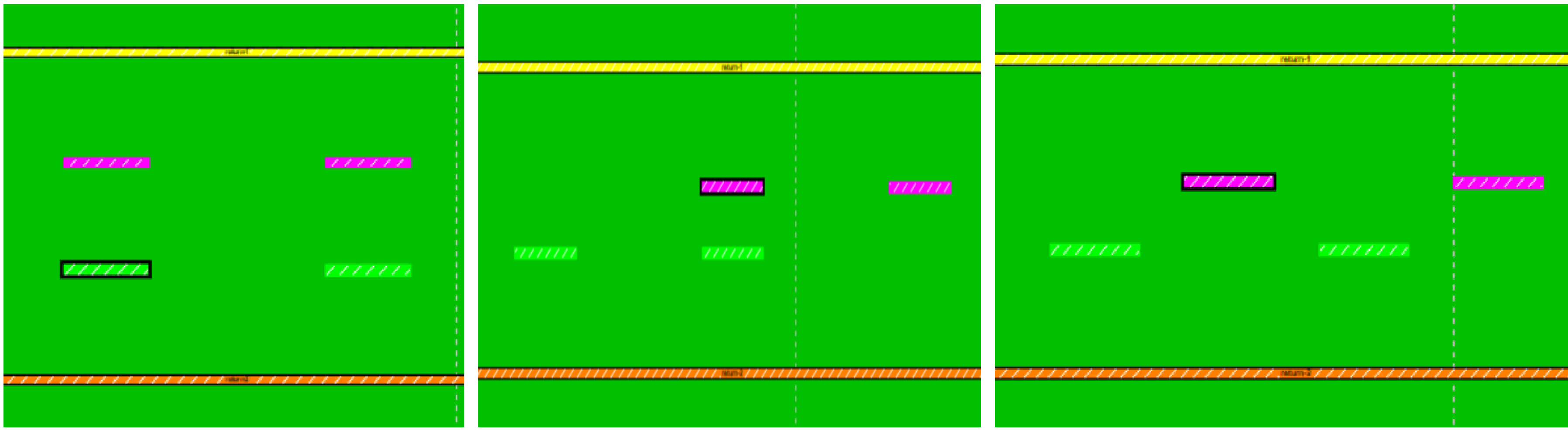
- Traces on top of each other across layers i.e. with zero offset have worst NEXT & FEXT numbers
- Traces with 2W offset have reasonable NEXT & FEXT numbers
- Return path gets shared to maximum when traces are on top of each other across layers. This results in ground bounce and hence worst NEXT & FEXT
- Poor Termination results in higher dI/dt in return current, higher Ground Bounce

Crosstalk in Broadside Coupled Single Ended Signals



- To further reduce NEXT & FEXT, spacing between signal layers needs to be increased while keeping the spacing between signal & reference same
- 2D field solver shows there is minimal return path sharing when signal layers are spaced far apart and traces are offset 2W vertically

Crosstalk in Broadside Coupled Differential Signals



- For Differential signals there exists a special case where NEXT goes to Zero
- Differential NEXT is maximum and positive when signals are on top of each other across layers
- Differential NEXT is maximum and negative when signals are offset such that +Ve signal of one layer falls on –ve signal of other layer
- There exists a spacing offset (~2W) between above 2 cases where zero NEXT occurs

Conclusion

1. Controlling Broadside side coupling/ground bounce is a challenge in high density boards. Better to avoid inadvertent broad side coupling
2. Return path needs to be ensured to be wide enough to contain return currents
3. Return path sharing to be avoided where ever possible
4. Orthogonal routing is best practical solution as it completely eliminates return path sharing

Acknowledgment

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